Fossil Energy's Oil and Gas Program

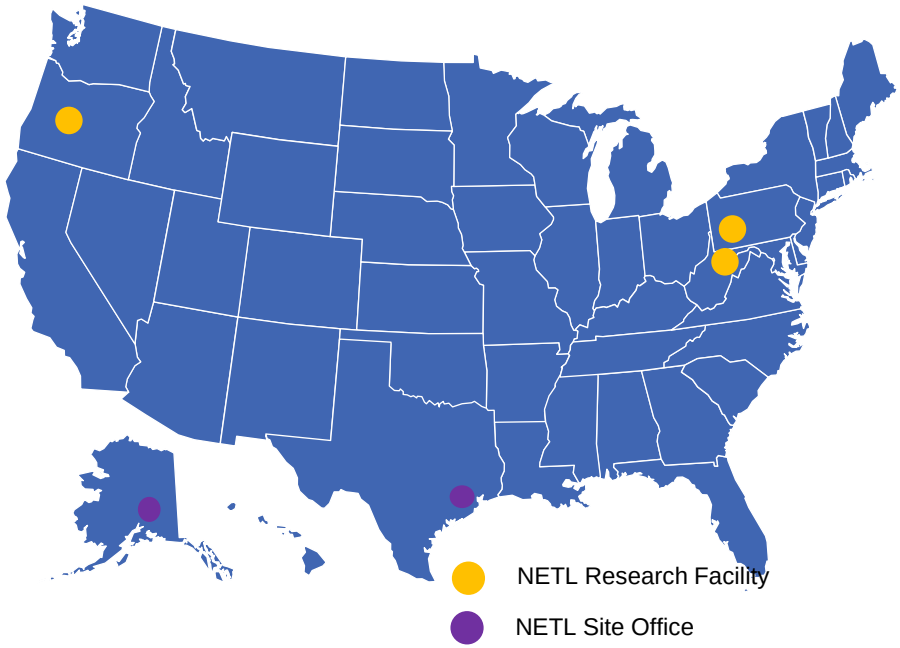
- Advancing Technologies to Ensure Safe and Prudent Oil & Gas Development

2014 Annual IOGCC Conference

Jared Ciferno
Strategic Center for Natural Gas and Oil
National Energy Technology Laboratory

National Energy Technology Laboratory

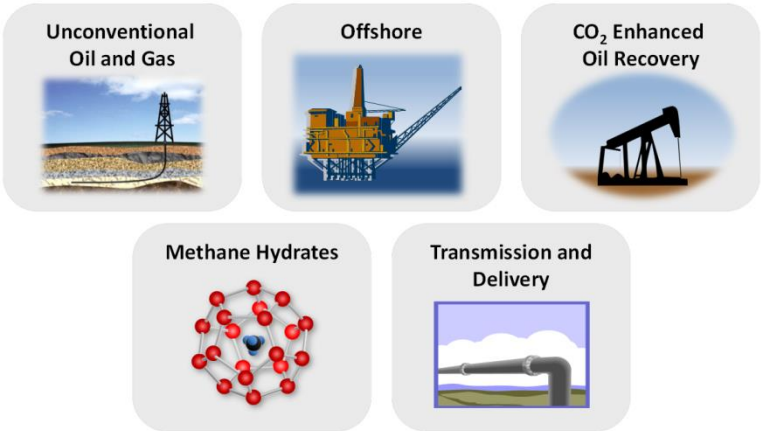
Implement technology programs that develop efficient, cost-effective technologies to ensure "safe and prudent development" of Natural Gas and Oil resources



Albany, OR ***Pittsburgh*** ***Morgantown***

Houston ***Anchorage***

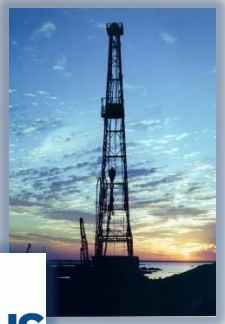
- A full service DOE research National Laboratory
- 5 Locations with 1,200 staff
- Dedicated to energy RD&D, domestic fossil energy resources
- Unique industry – academia – government collaborations



Unconventional Oil and Gas Research Focus

Maximum recovery, minimal environmental impact

Unconventional



FracFocus Chemical Disclosure Registry

Minimizing Environmental Impacts

Resource Characterization
Water Quantity & Quality
Air Quality
Induced Seismicity

- **Resource Characterization/Optimization**
  - Fundamental Science: Hydrocarbon storage and release; Fracture growth and control
  - Constraining Development Intensity (Maximize per well drainage & efficiency)
- **Water Quality**
  - Pathways for groundwater connection
  - Legacy well identification
  - Cement materials/diagnostics for extended well-bore integrity
  - Effective water treatment and management
- **Air Quality**
  - Measurement, Analyses, Attribution
  - Wellbore integrity
- **Water Availability**
  - Smarter use of water in hydraulic fracturing
  - Alternatives to fresh water
- **Induced Seismicity**
  - Data collection and modeling analysis
  - Wastewater injection

Multi-Agency Collaboration

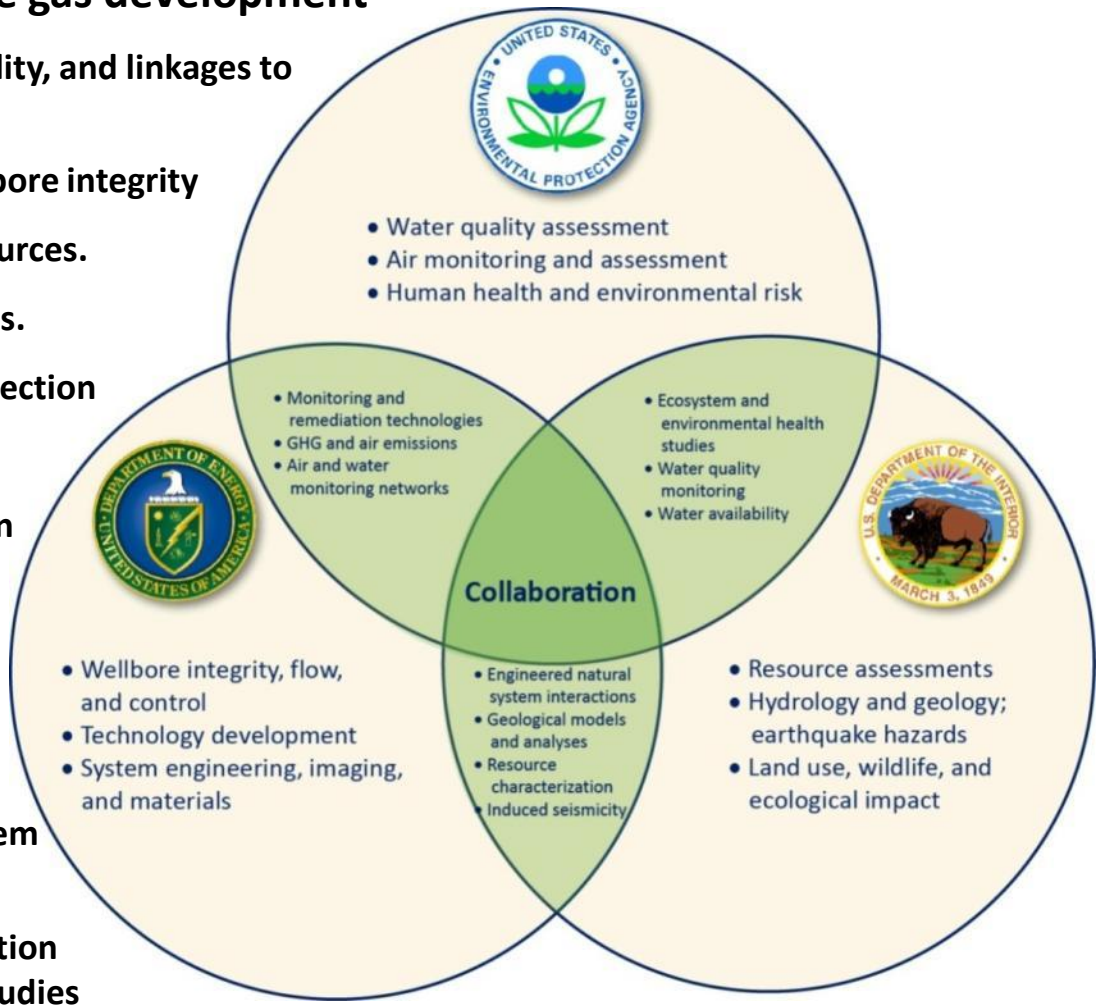
DOE/EPA/DOI

Minimizing the EHS impacts of shale gas development

- **Resource Characterization: nature, variability, and linkages to EHS impacts**
- **Water Quality: treatment, disposal, well-bore integrity**
- **Water Quantity: smart use, alternative sources.**
- **Air Quality/GHG: traffic, fugitive emissions.**
- **Induced Seismicity: during wastewater injection**
- **Ecosystems: fragmentation, noise, light**
- **Human Health: topics still under discussion**

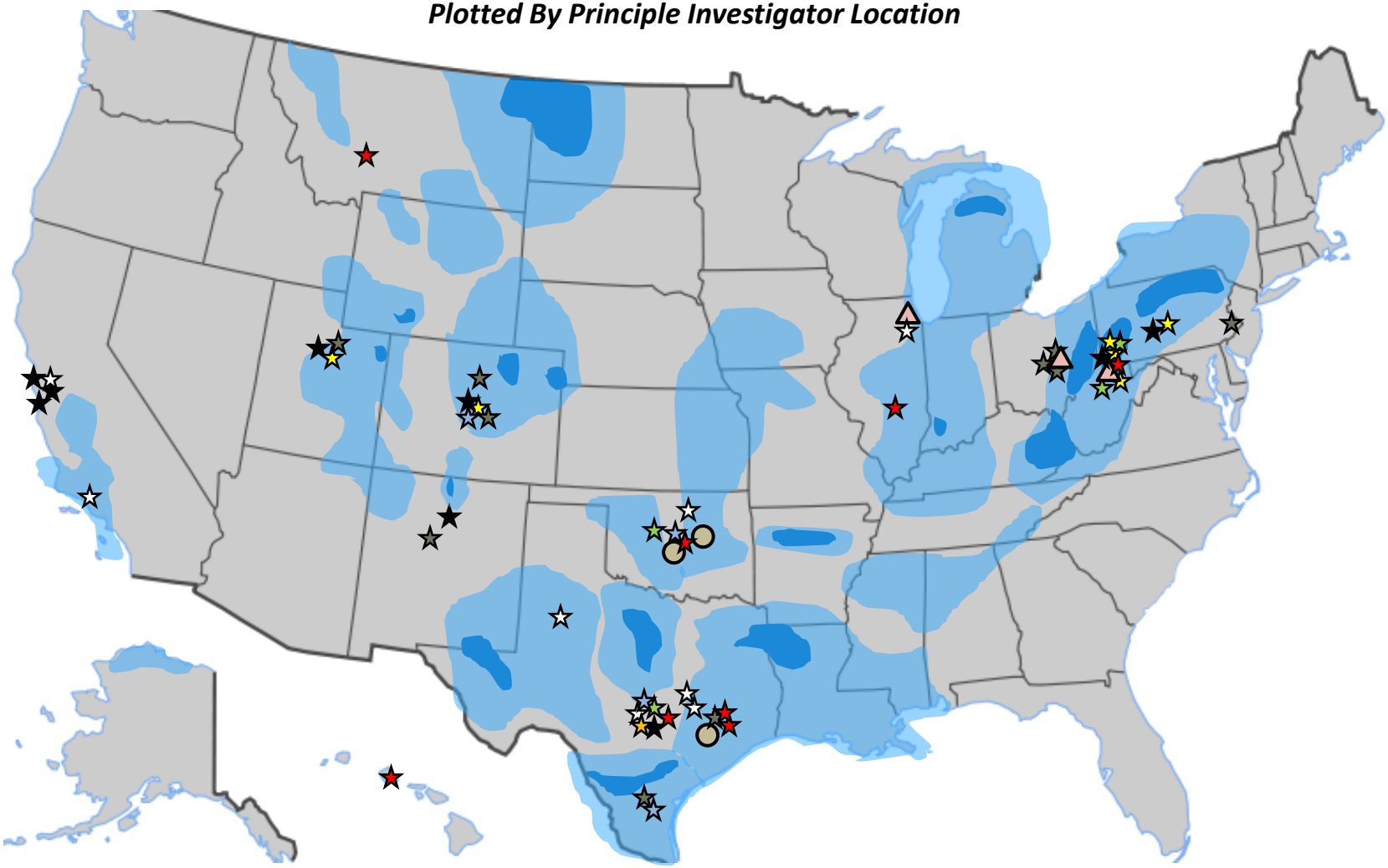
DOE Focus

- **Development and implementation of Technological Solutions (impact avoidance and mitigation)**
- **Analyses of various aspects of energy system performance and subsurface modeling**
- **Scientific contributions to field data collection and interpretation, including laboratory studies**



52 Active DOE Projects: Onshore Unconventional Oil and Gas Resources - 2015

Plotted By Principle Investigator Location



TOPIC 1: Basic Sci.
1. SNL
2. LBNL
3. LANL
4. U.Texas-Austin
5. Penn St. U.
6. Utah GS
7. NETL-ORD
8. CSM
9. SLAC

TOPIC 1: Rec. Efficiency
1. GroundMetrics
2. Oklahoma St. U.
3. Gas Tech. Institute
4. TEES
5. Texas A&M (2)
6. U. Texas-Austin
7. Texas Tech U.

TOPIC 2: Water Treat/Mgmt.
1. GSI
2. NMIM&T
3. Col. St. U.
4. Drexel U.
5. Utah GS
6. SwRI
7. U. Texas-Austin
8. Ohio U.
9. U. So. Cal.
10. Battelle (2)
11. CSM

TOPIC 2: Well Integrity
1. CSI Tech (2)
2. Oceanit
3. NETL-ORD
4. GE Global
5. Montana St. U.

TOPIC 3: Water Use
1. Col. School Mines
2. U. Texas-Austin
3. SwRI

TOPIC 4: Air Quality
1. Utah State
2. Col. School Mines
3. Penn State
4. Carnegie Mellon U.
5. West Va. U.
6. NETL-ORD

TOPIC 7: Seismicity
1. West Va. U.
2. UT-Austin
3. U. Oklahoma
4. NETL-ORD

Field Laboratories (Cross-cut all Topic Areas)
1. West Va. U.
2. Ohio St. U
3. GTI

Outreach/Tech Transfer
1. HARC
2. PTTC
3. GWPC

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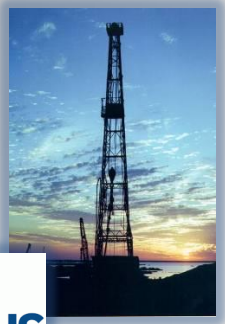

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  - Measurement, Analyses, Attribution
  - Reconciling Top-Down/Bottom Up
- **Water Availability**
  - Smarter use of water in hydraulic fracturing
  - Alternatives to fresh water
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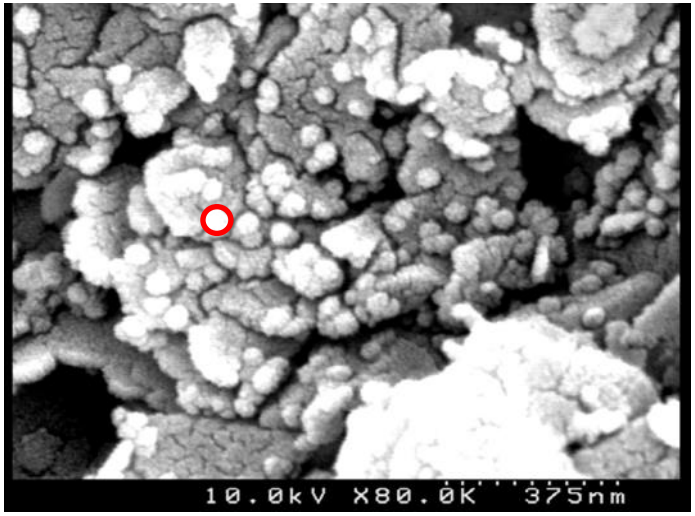
  - Data collection and modeling analysis
  - Wastewater injection

Improved Drilling and Fracturing Fluids

Objective:
Develop new, water-based drilling and hydraulic fracturing fluids to inhibit water invasion into shales, thereby improving wellbore stability and reduce formation damage in reactive (water sensitive), hydrocarbon-bearing shales

Advantages:

- Replace organic (diesel)-based drilling muds with *nanoparticle water-based* muds …….. ↑ wellbore stability, ↓ environmental impact
- Reduce water invasion into shales during completion……↓ formation damage, ↓ water use, ↑ productivity, ↓ drilling intensity
- Lower cost drilling, lower cost HF treatments, lower overall water use, higher productivity wells. "More gas from fewer wells"



20nm nanoparticles relative to shale pore throats in SEM photo

Partner: University of Texas-Austin

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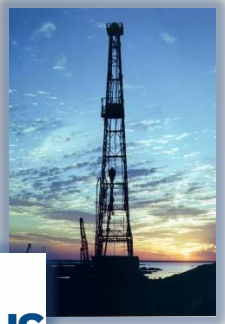

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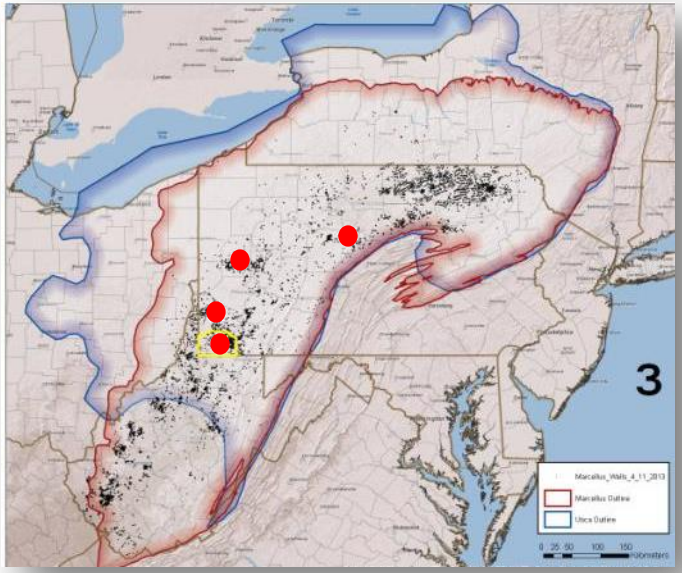
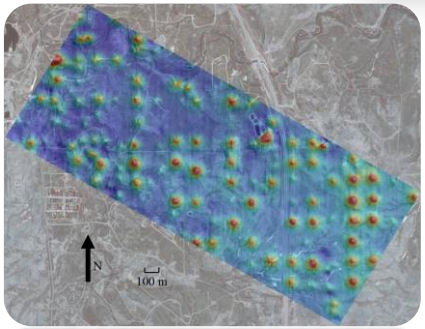
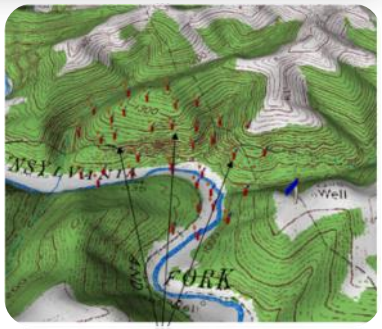
NETL

NETL ORD Marcellus Shale Field Studies

- **Efforts in four counties at multiple sites with multiple industry and academic partners**
- **Baseline monitoring and impact assessment experiments**
- **Field data collection largely completed; analysis underway**







Air Quality Soil Gas Abandoned Wells Water Quality Microseismic Fluid Migration Ecological

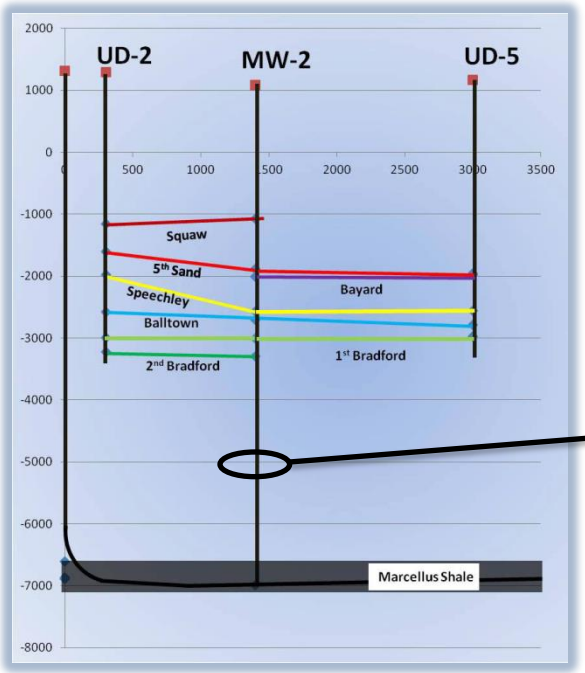
Rock Properties Chemical Transformation Induced Seismicity

Water Quality: Pathways to Groundwater

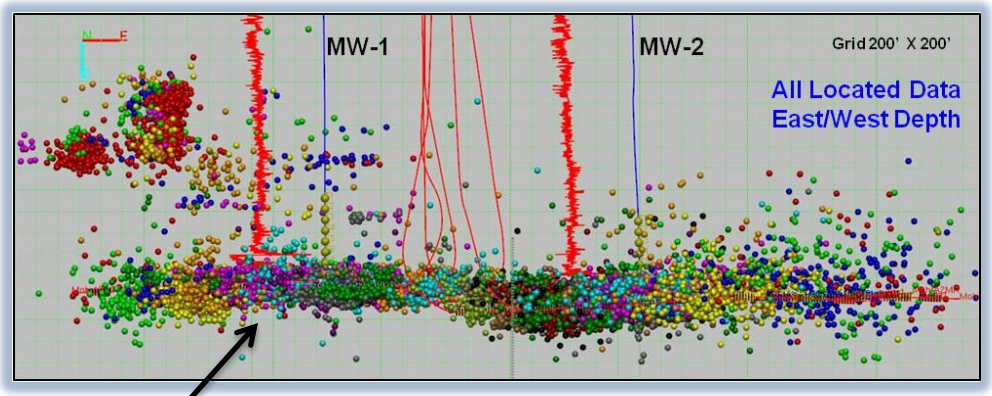
Evaluating Fracture Growth

Objective: Monitor induced fracturing of six horizontal Marcellus Shale gas wells in Green County, PA to determine…

1. The maximum height of fractures
2. Whether natural gas or fluids migrated—before, during, or after hydraulic fracturing – from the Marcellus Shale into a producing Upper Devonian/Lower Mississippian gas field 3,800 above the Marcellus Shale



7,000 feet



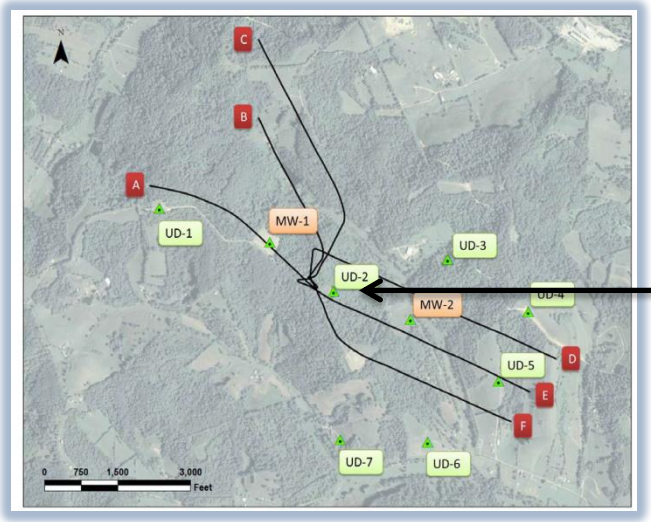
Fracture Height
Two vertical Marcellus wells served as microseismic monitoring wells

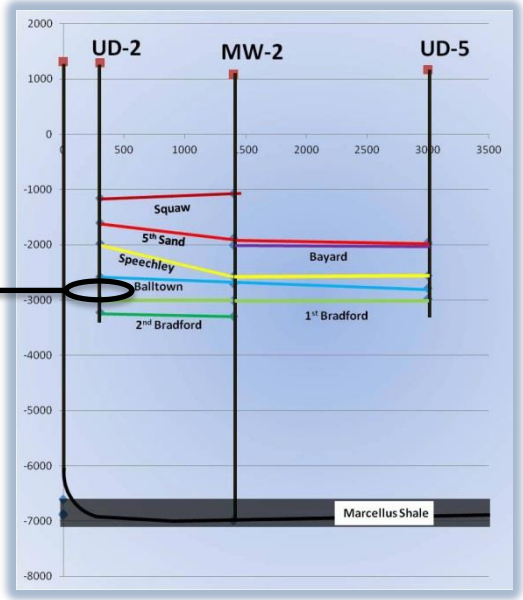
Water Quality: Pathways to Groundwater

Evaluating Fracture Growth

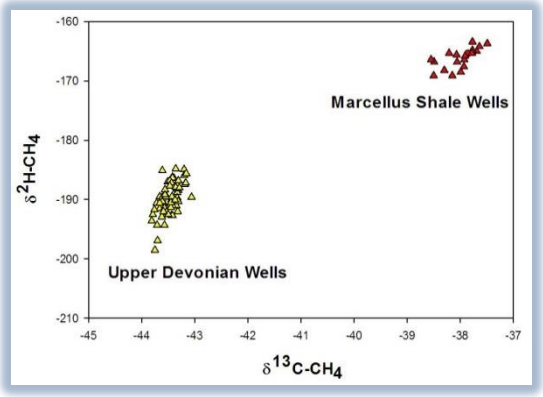
Assessing natural gas or fluids migration

7 vertical gas wells completed in multiple, thin sands 3,800 – 6,100 ft above the six horizontal Marcellus Shale wells

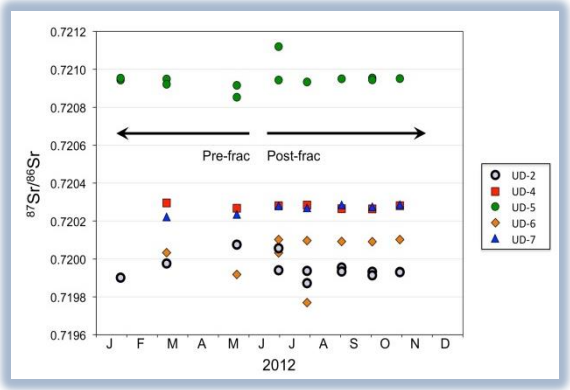




CH_4 Isotope Monitoring



Produced Water Isotopes



Results

1. Microseismic events occurred 5,000 feet below drinking water aquifers
2. Gas Migration: No evidence of migration 2 month prior to and 8 months following hydraulic fracturing
3. Fluid Migration: No evidence of migration 2 months prior to and 5 months after hydraulic fracturing

Water Quality: Pathways to Groundwater

Identifying Legacy Wells

Background

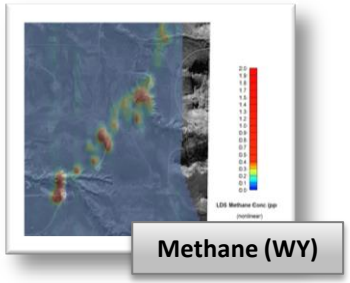
- Potential for legacy wellbores to provide rapid path for fluid-flow to groundwater

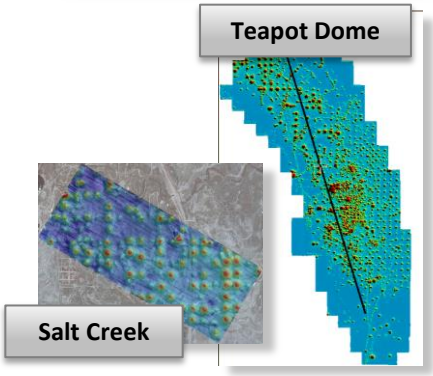
Objectives

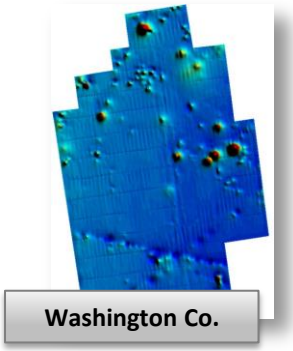
- To develop & demonstrate method for rapidly locating legacy wells at the field scale over ranges in topography, vegetation, and well completion (age; no casing; …)

Field Sites

- **Teapot Dome & Salt Creek, WY (RMOTC; Anadarko)**
  - Western conditions (flat terrain; minimal vegetation)
  - Validated with ground-based surveys
- **Washington County, PA (MCC Partners; Range)**
  - Evaluated for eastern conditions (topography; vegetation)
- **Washington County, PA—Hillman State Park (PA-DEP, PA-DCNR)**
- **Potter County, PA—Ole Bull State Park (PA-DEP, PA-DCNR)**
- **Venango County, PA—Oil Creek State Park (PA-DEP, PA-DCNR)**

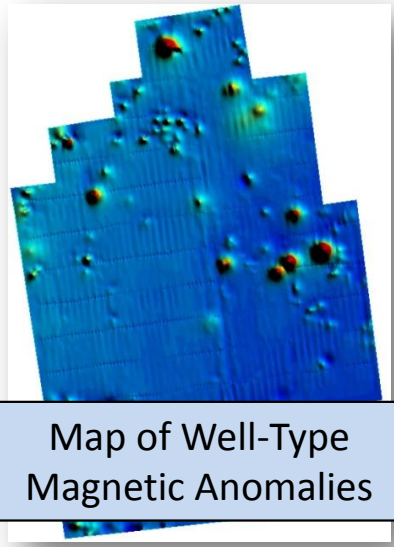






Water Quality: Pathways to Groundwater

Identifying Legacy Wells



Map of Well-Type Magnetic Anomalies

Navigating to Magnetic Anomaly Location

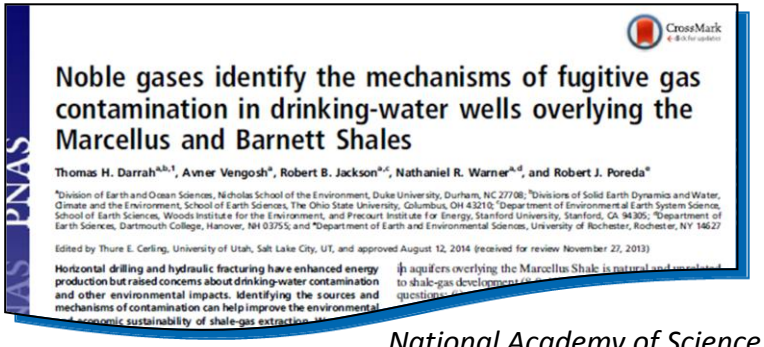
Locating Magnetic Anomaly on the Ground

Excavation to Confirm Well Location

Water Quality: Pathways to Groundwater

Wellbore Integrity

Today, fugitive gas contamination in drinking water wells overlying unconventional shale gas development has been linked to poor wellbores.



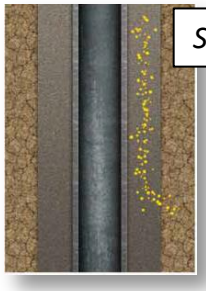
National Academy of Science

Objectives

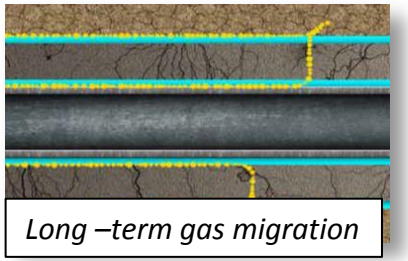
Perform a systematic and comprehensive study of the cementing process applied in UOG operations; identify deficits; develop solutions to ensure 100% zonal isolation

Field Sites

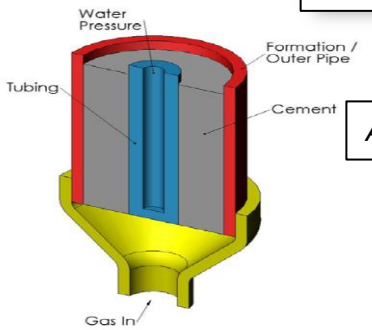
- **120 Marcellus wells; 2 service companies**
- **Field observations/Cement placement**
  - Borehole geometry, pipe centralization, drilling fluid properties, mud removal practices, casing rotation, etc.
- **Field samples tested in lab**
  - Rheology, fluid loss, free water, thickening time, compressive strength, short term gas migration
- **Annular seal durability test**
  - Assess failure at the cement to pipe interface during stimulations (10,000 psi)



Short –term gas migration



Long –term gas migration



Annular seal durability

RPSEA Project. Team: CSI Technologies, Chesapeake, Univ. of Houston

CSI TECHNOLOGIES
A SUPERIOR ENERGY SERVICES COMPANY

Source: Darrah , T., et al, National Academy of Science, 2014, www.pnas.org/cgi/doi/10.1073/pnas.1322107111

NETL

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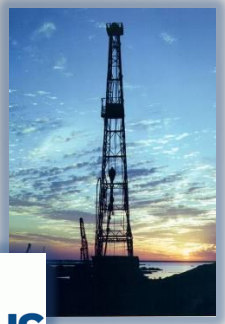

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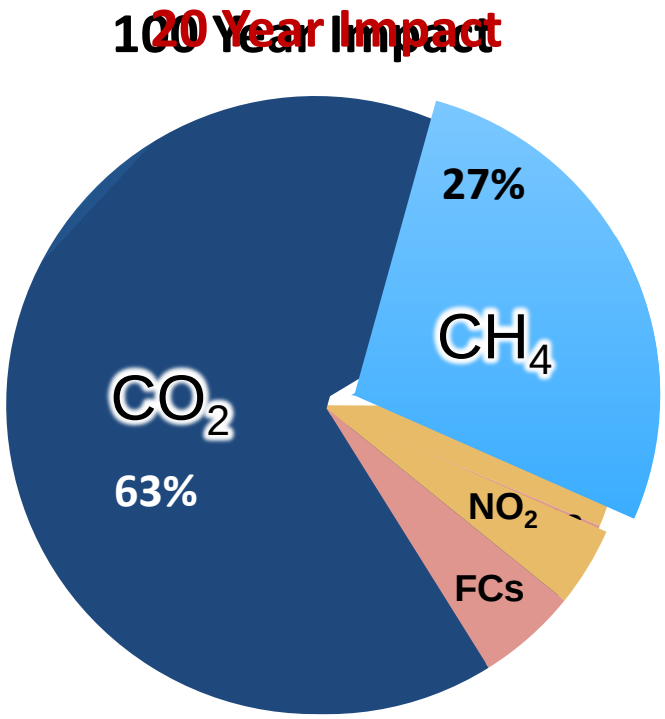
NETL

Methane Emission Reduction

"Why is this important?"

- Reducing CO_2 is still an urgent priority to stabilize the climate system
- Methane is the 2nd biggest contributor to overall greenhouse gas effect – especially in the near term
- Reducing methane emissions slows the rate of climate change, and can reduce peak warming
- Safety & Economics



Total 2012 GHG emissions
6,526 MM Tonne CO_2 Equivalent

EPA: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2012, April 15, 2014
IPCC AR 5:Climate change 2013, working group 1, "The Physical Basis" Pg. 714
IPCC AR2 Climate change 1995, working group 1, "The Science of Climate Change", Pg. 22

Natural Gas Systems were responsible for 23% of Total U.S. Methane Emissions in 2012

*As Natural Gas Travels from Extraction to Distribution, approximately **323 Bcf** (6,186 Gg) of Methane is Lost to the Atmosphere Every Year as Emissions.*

104 Bcf	47 Bcf	108 Bcf	64 Bcf
			
Field Production	Natural Gas Processing	Transmission and Storage	Distribution

EPA: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2012, April 15, 2014

Top-Down versus Bottom-Up Measurements

"Top down" methods - Measure the amount of methane in the atmosphere from a height sufficient to capture a whole area's emissions

Weaknesses:

Are we accounting for other sources (e.g., swamps, landfills, abandoned wells, etc.)?
Are we accounting for dispersion?
Are conditions representative?

"Bottom up" methods – Quantify methane emissions at the source (each type of device) and estimate total by counting the numbers of contributing devices

Weaknesses:

Are device counts accurate?
Are avg. leakage rates representative?
Are we missing any leaks?

Methane Emission Reduction

Research Needs

Scientifically quantify emissions

- Identify and improve source/component measurements **in the field**
- Improve atmospheric measurements and modeling estimates
- 6 active field projects

Colorado School of Mines · The University of Utah · Penn State · Carnegie Mellon · West Virginia University · NETL

Life cycle analysis

- Understand temporal, technological, play level, and other key emission source differences
- Reducing single year activity bias → evaluate methane emissions over a 30-year operating perspective
- What are the true costs and benefits associated with incremental reductions?

Methane Emission Reduction

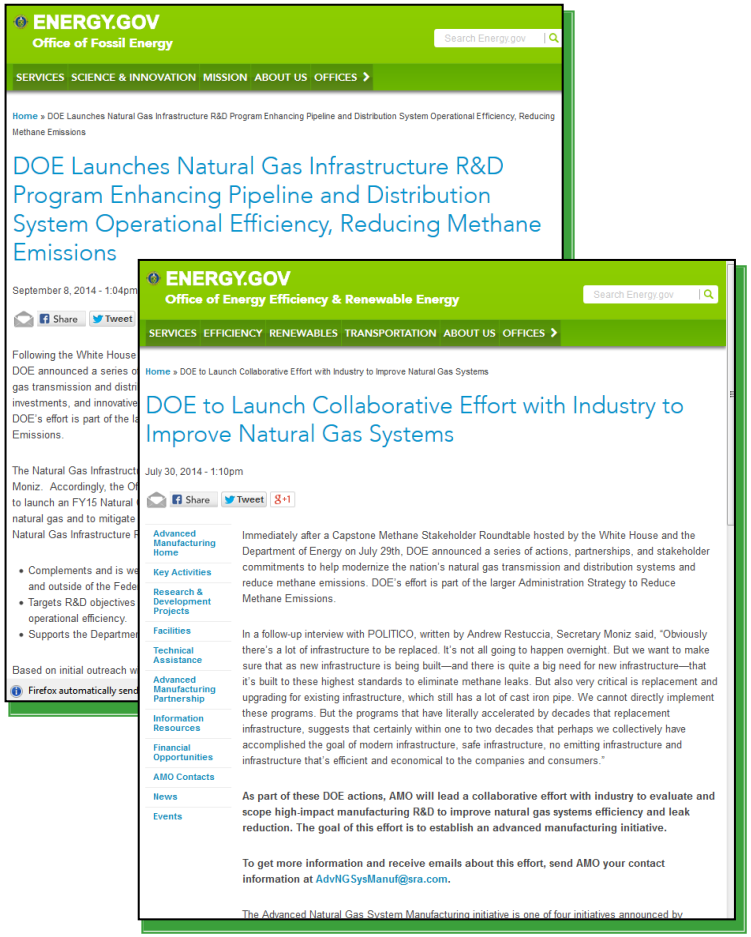
Technology Development Needs

Planning for Fossil Energy's Natural Gas Transmission and Delivery R&D Program (~ $5 Million)

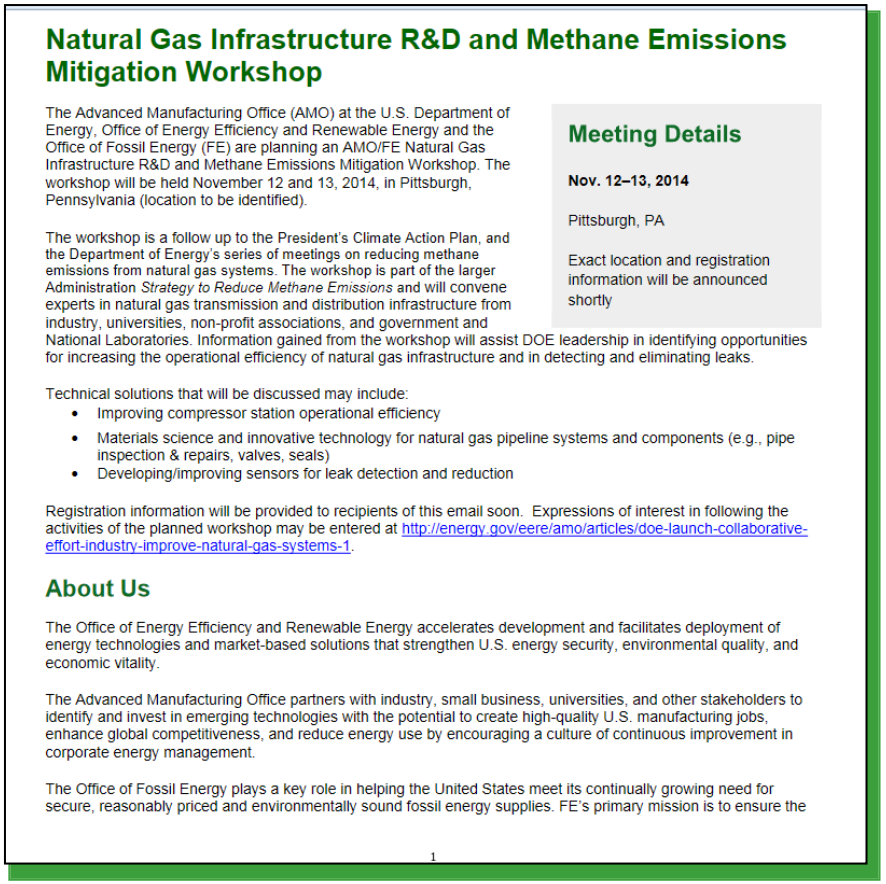
Fiscal Year 2015 Research Areas

- External Leak Detection & Monitoring
  Identification, measurement of methane leaks
- Pipeline Inspection & Repair
  Reduce need to evacuate gas from the pipe
- Improve Reciprocating Compressor Performance
  Increase efficiency, capacity; reduce emissions
- Smart Sensors for Pipeline Operational Efficiency
  Continuous in-pipe communication of operational parameters

Government/Industry NG Infrastructure R&D Strategy Workshop



http://energy.gov/fe/articles/doe-launches-natural-gas-infrastructure-rd-program-enhancing-pipeline-and-distribution



Natural Gas Infrastructure R&D and Methane Emissions Mitigation Workshop

The Advanced Manufacturing Office (AMO) at the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy and the Office of Fossil Energy (FE) are planning an AMO/FE Natural Gas Infrastructure R&D and Methane Emissions Mitigation Workshop. The workshop will be held November 12 and 13, 2014, in Pittsburgh, Pennsylvania (location to be identified).

Meeting Details

Nov. 12–13, 2014

Pittsburgh, PA

Exact location and registration information will be announced shortly

The workshop is a follow up to the President's Climate Action Plan, and the Department of Energy's series of meetings on reducing methane emissions from natural gas systems. The workshop is part of the larger Administration *Strategy to Reduce Methane Emissions* and will convene experts in natural gas transmission and distribution infrastructure from industry, universities, non-profit associations, and government and National Laboratories. Information gained from the workshop will assist DOE leadership in identifying opportunities for increasing the operational efficiency of natural gas infrastructure and in detecting and eliminating leaks.

Technical solutions that will be discussed may include:

- Improving compressor station operational efficiency
- Materials science and innovative technology for natural gas pipeline systems and components (e.g., pipe inspection & repairs, valves, seals)
- Developing/improving sensors for leak detection and reduction

Registration information will be provided to recipients of this email soon. Expressions of interest in following the activities of the planned workshop may be entered at http://energy.gov/eere/amo/articles/doe-launch-collaborative-effort-industry-improve-natural-gas-systems-1.

About Us

The Office of Energy Efficiency and Renewable Energy accelerates development and facilitates deployment of energy technologies and market-based solutions that strengthen U.S. energy security, environmental quality, and economic vitality.

The Advanced Manufacturing Office partners with industry, small business, universities, and other stakeholders to identify and invest in emerging technologies with the potential to create high-quality U.S. manufacturing jobs, enhance global competitiveness, and reduce energy use by encouraging a culture of continuous improvement in corporate energy management.

The Office of Fossil Energy plays a key role in helping the United States meet its continually growing need for secure, reasonably priced and environmentally sound fossil energy supplies. FE's primary mission is to ensure the

1

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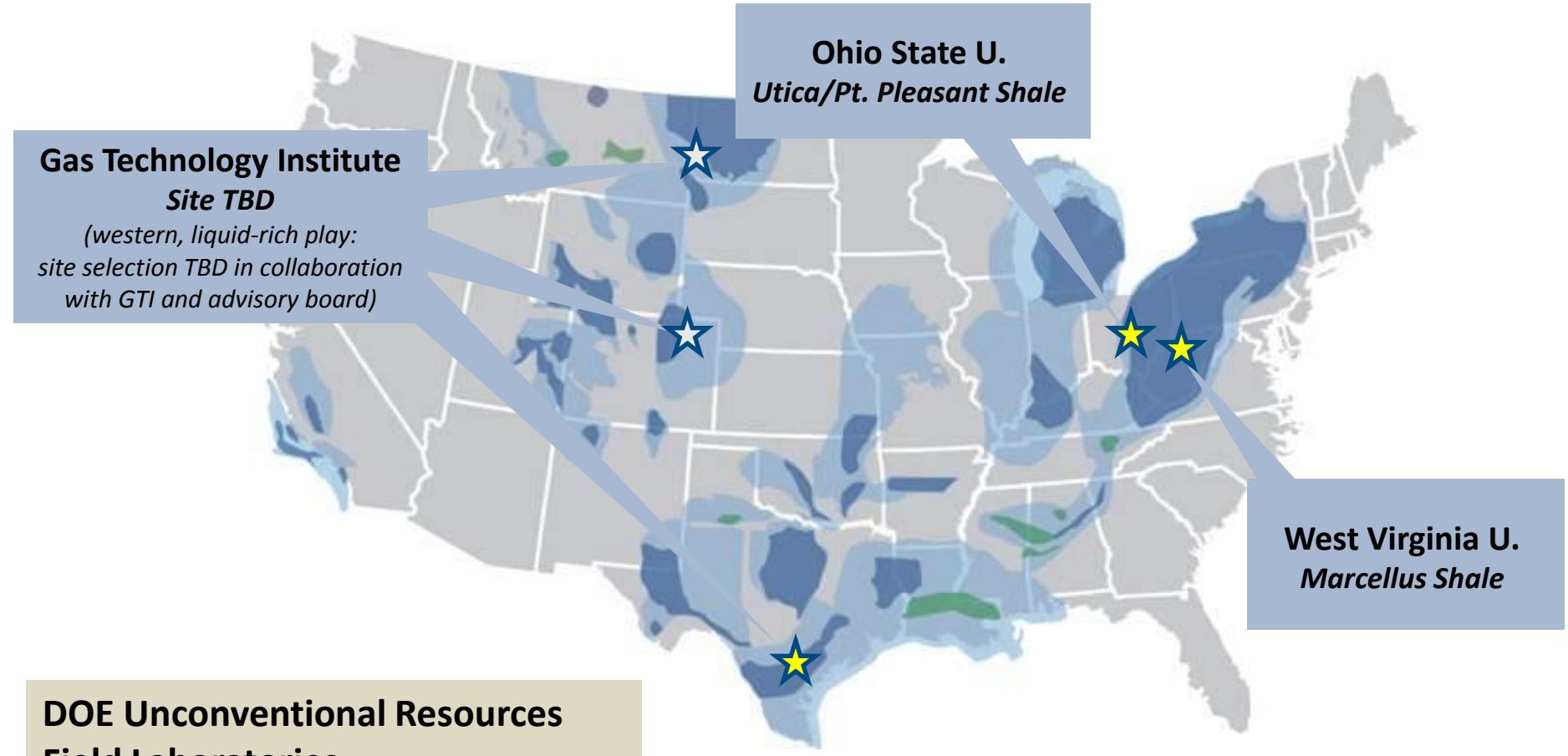
Or www.yesevents.com/AdvNGSysManuf

Field Laboratories



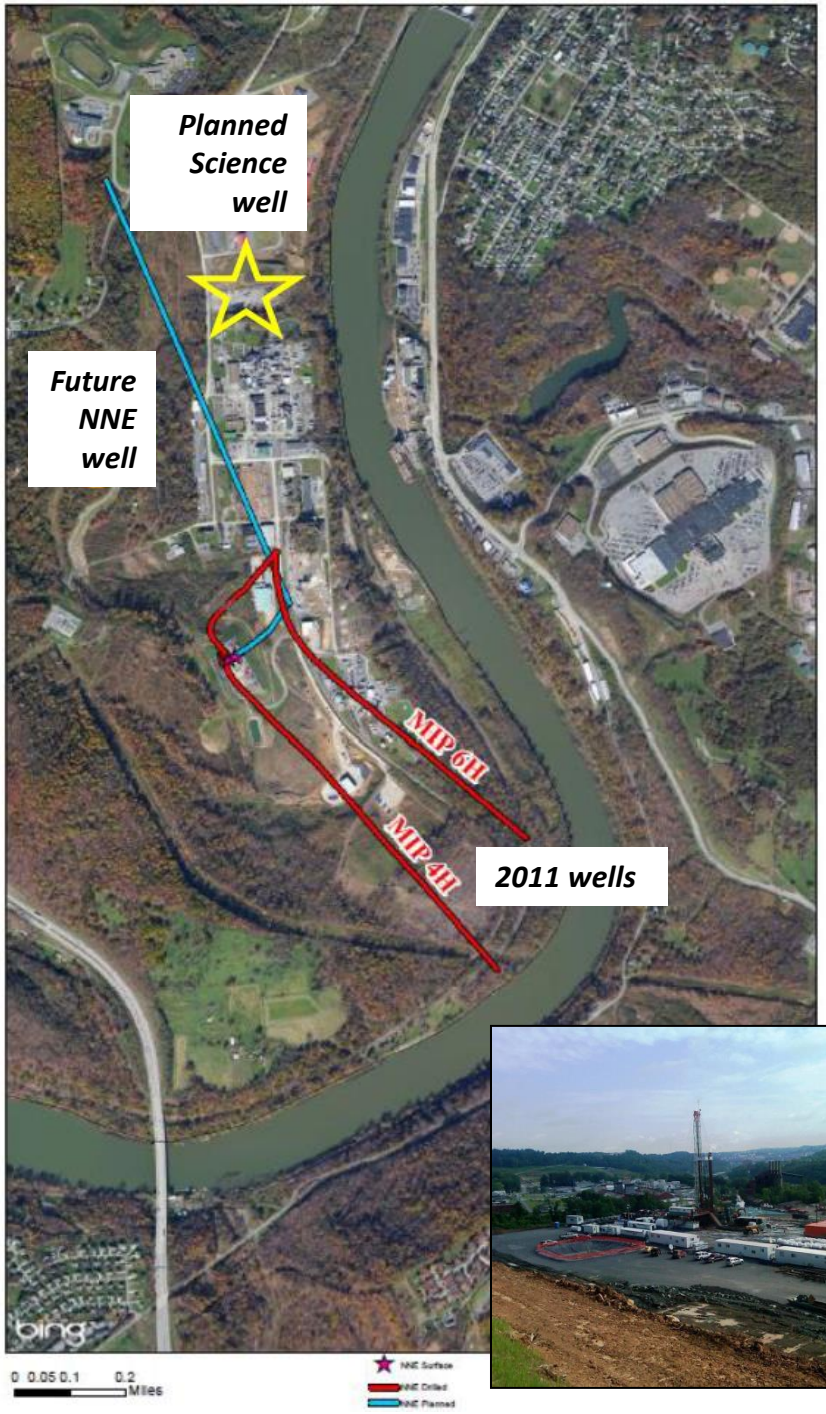
DOE Unconventional Resources Field Laboratories

- *Baseline and Real-time Air, Water, Land impact Monitoring*
- *Vertical Science/Observation Wells*
- *Instrumented Production Wells*
- *Technology Testing/Demonstration Sites*
- *Broad Collaborative Opportunities*
- *Public & International Outreach/Training*

Will Fulfill Need…

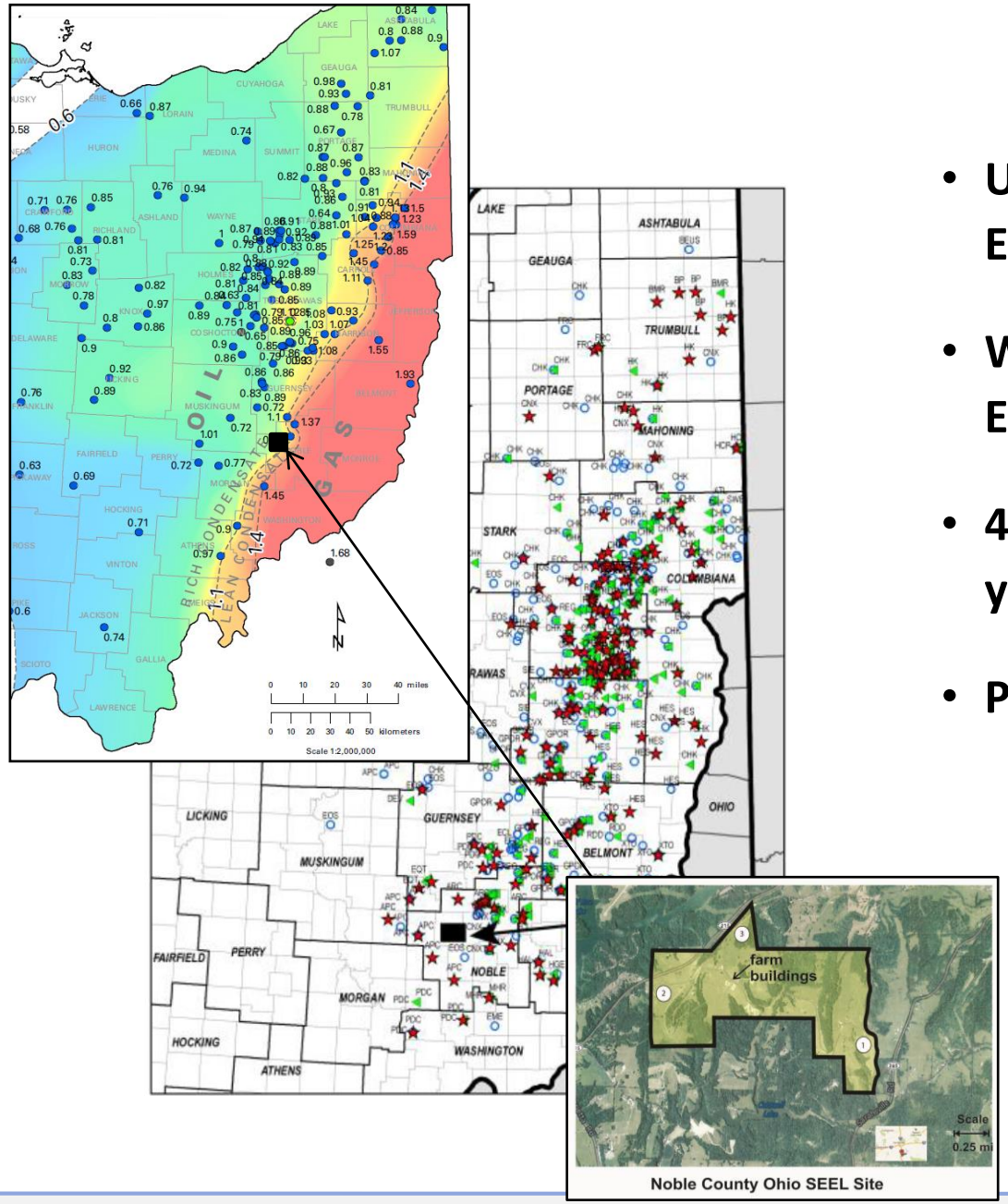
- *…of states for specific outreach and training*
- *…to objectively observe and document impacts from business-as-usual UoG development.*
- *…to enable science via wells with a stated primary purpose of science – not prone to vagaries, time sensitivity of industry wells*
- *…to provide locations for timely testing of promising, pre-commercial, new mitigation approaches, technologies.*

West Virginia U.

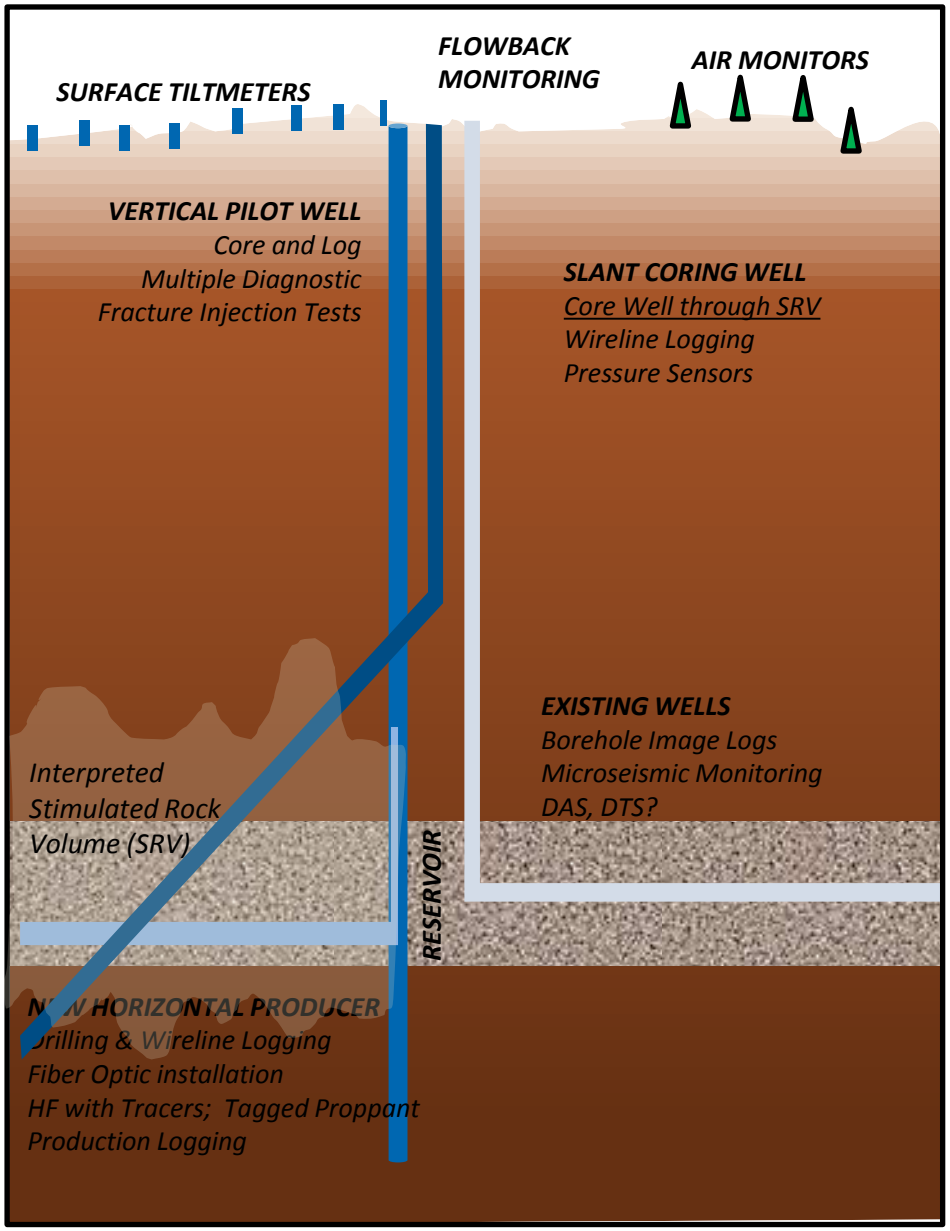


- **Marcellus Shale Energy and Environment Laboratory**
- **Ohio State & Northeast Natural Energy**
- **5 yrs: $10 M: $7.4 M DOE**
- **Site provides**
  - Dry Gas setting in heart of established play
  - Long history of environmental monitoring
  - Ability to characterize UOG processes and monitor UOG impacts at an active well site
  - Vertical Science well in advance of future Marcellus horizontal wells
  - Multiple future wells likely

Ohio State U.



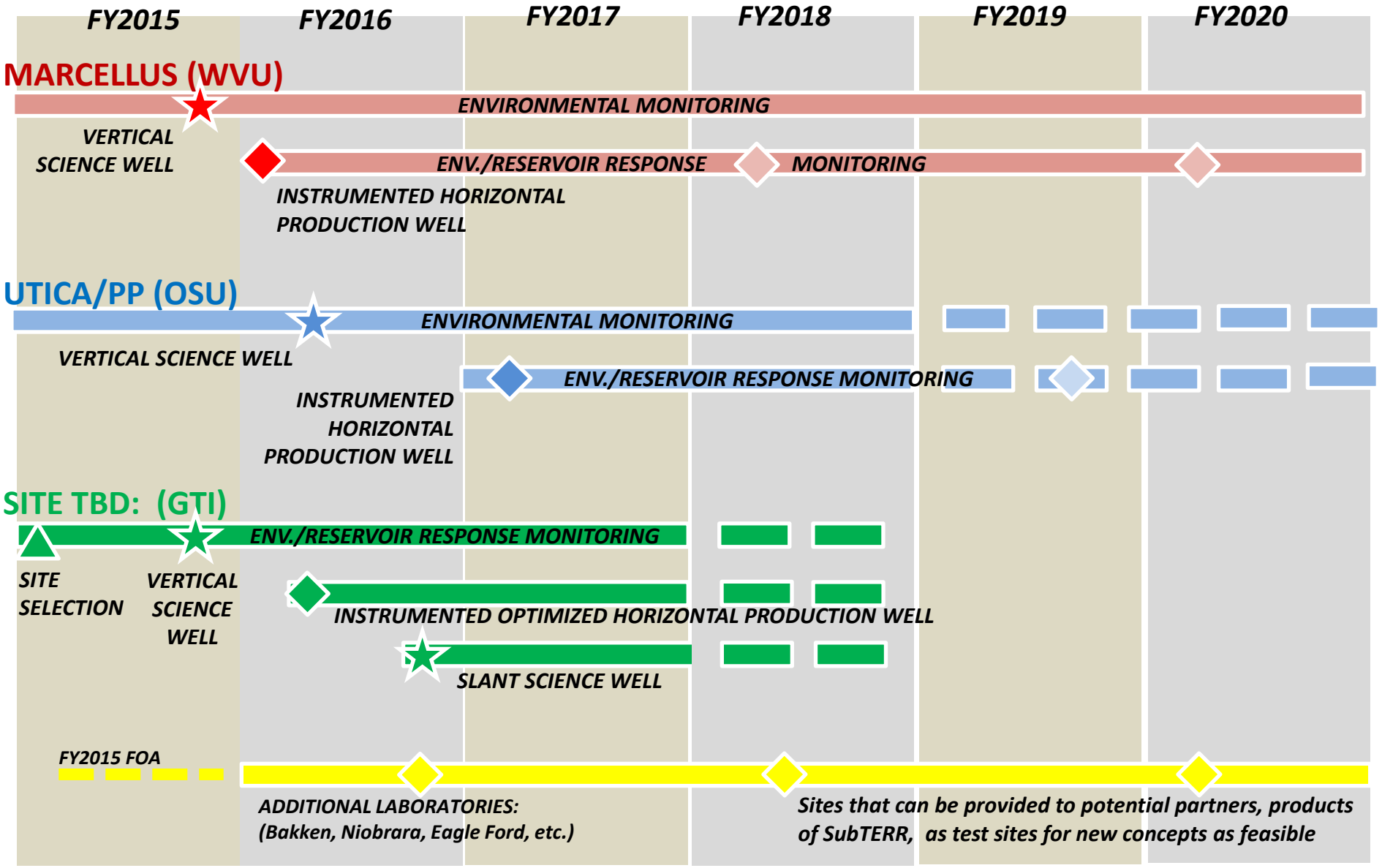
- **Utica Shale Energy and Environmental Laboratory**
- **WVU, Ohio U., U Texas, CSI, GSI, EFD, Miami U.**
- **4 yrs: $11.6M; $7M DOE (4 years)**
- **Project Features**
  - "Rich condensate" setting of emerging play
  - OSU commitment to sustaining the site as long-term shale gas laboratory



Gas Technology Institute

- **Hydraulic Fracturing Test Site**
- **Operator & Site: TBD**
  - Looking for an oil play west of Miss.
  - Currently, evaluating Niobrara or Wolfcamp
- **3 yrs: Est. $12 M: $7 M DOE**
- **Project Features**
  - Extensive Industry Participation
  - HF fracture design informed by prior GTI projects
  - Air, Groundwater, Flowback Water Monitoring
  - Comprehensive Geophysical Evaluation (microseismic, DAS/DTS, tiltmeter)
  - Full Science Program (core analysis, microbiology…)
  - Collaborative pilot well, production well, and slant core well planning.
- **Recommendation**
  - Focus on one site that complements other DOE HF field laboratories. Assume 60% of budget.

UoG Field Laboratories – Potential Timeline



For More Information

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